



E/CONF.39/D/12

26 Sept.1962

ORIGINAL : ENGLISH

**UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS**

Agenda Item: D.11.1

India

**INDUSTRIAL DEVELOPMENT-SCIENTIFIC AND TECHNICAL FACTORS
IN CHOICE OF FERTILISERS AND RAW MATERIALS**

By G.P. KANE,
M.N. KALE,
Development Wing,
Ministry of Commerce
and Industry,
New Delhi, India

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UNITED NATIONS CONFERENCE
ON
THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF LESS DEVELOPED AREAS

Agenda Item : D : INDUSTRIAL DEVELOPMENT

D.11.1 : Scientific and technical factors
in choice of fertilisers and
raw materials.

By
G.P. Kane and M.N. Kale
Development Wing, Ministry of Commerce & Industry,
New Delhi (India)

Introduction:

1. The importance of fertilisers for increasing crop yields is now accepted. Formerly, there was considerable controversy about the relative merits of manures and chemical fertilisers. The superiority of organic manures for maintaining better soil texture as well as its capacity to retain moisture is well-known. The physical effort involved in the collection of organic manures such as town refuse and compost, as well as the cost of their transport to the point of usage, however, set a limit to their application. The use of chemical fertilisers is therefore unavoidable if the growing world demand of food is to be met.

2. The crop yield per acre has been used often for comparing soil fertility. Such a comparison between two areas may give rise to misleading conclusions, if they have not been under cultivation for the same period of time. For example, the yields per acre of cereals in India would appear very low compared to those in Europe or in the United States, if the effect of centuries of cropping and inadequate manuring of Indian soils is overlooked. The comparison does help, however, to bring out the urgent need for application of chemical fertilisers to such soils for stimulating higher yields per acre currently as well as for building up soil fertility on a long-term basis.

3. The three essential plant nutrients are nitrogen, phosphorus and potassium. In terms of paddy the application of a pound of fertiliser nitrogen increases the yield by about 10 lbs., whereas for a pound of phosphorus it is lower, at about 7 lbs. The response to the application of phosphorus is slow, but it is well-known that unless the availability of phosphorus in the soil is maintained, the response to added nitrogen begins to fall. Thus, it is necessary to step up the

application of phosphorus along with nitrogen, the preferred proportion being 1 of N to 1 of P_2O_5 . Potassium is important particularly for garden crops. Other plant nutrients such as calcium, sulphur, and trace elements are usually available in the soil; whenever any particular deficiency develops, it can be corrected by the application of compounds containing these elements along with nitrogenous fertilisers.

Types of Fertilisers:

4. By-product ammonium sulphate from coke ovens of steel works was recognised early as a source of fertiliser nitrogen. It is obtainable in yields of the order of 30 lbs. per ton of steel. When the demand for ammonium sulphate increased beyond its availability as a coke oven by-product, materials based on synthetic ammonia were developed for use as fertilisers. The first such fertiliser introduced in Norway was calcium nitrate. This was followed by synthetic ammonium sulphate and subsequently by other nitrogenous fertilisers including calcium cyanamide, ammonium nitrate, urea, and ammonium chloride. A recent innovation is the use of anhydrous ammonia by direct application of the gas to the soil. It is claimed that when injected six inches below the freshly broken surface, ammonia is completely retained by the moisture present in the soil, and that by this method the cost of application of fertiliser nitrogen is reduced considerably. Similarly, it is suggested that large compact areas can be supplied with nitrogenous fertilisers at low cost by adding ammonia to irrigation water.

5. Formerly, fertiliser mixtures were used for supplying simultaneously more than one plant nutrient. The mixtures were prepared by compounding chemicals containing nitrogen, phosphorus and potassium, that were produced separately. A recent tendency is to produce compounds that contain more than one plant nutrient. The principal products of this type are ammonium phosphate and nitro-phosphate. The relative proportion of nitrogen and phosphorus in the final product can be adjusted to the desired ratio by admixture of ammonium sulphate or urea to these products and processing the mixture into granules. Salts of potassium or other plant nutrients can also be incorporated.

6. Ammonium sulphate is a free flowing fertiliser and, therefore, very convenient whenever manual application is necessary. This explains its popularity in tea gardens where fertiliser must be applied near the roots of standing plants. The nitrogen content of commercial fertilisers is given below in Table I.

TABLE I

Fertiliser		Content of Nitrogen Per cent.	
Ammonium sulphate	...	...	20
Ammonium nitrate	...	...	33 to 34
Calcium ammonium)	) ...	(1)	20.5
nitrate		(11)	26
Ammonium sulphate nitrate	...	...	26
Ammonium chloride	...	...	32
Urea	...	...	45

In different countries, the price of fertilisers to farmers varies from Rs.0.7 to 1.6 per kilogram of N in the form of ammonium sulphate. With the other fertilisers, Nitrogen is generally available at a lower price per kg., but some difficulties may arise. For instance, due to its hygroscopic nature, urea must be packed in a bag with an impervious lining and the entire contents of the bag used immediately after it is opened. Filled ammonium nitrate is used extensively in Europe, but it is still not popular in tropical countries because of its hygroscopic character and also the risk of fire or explosion if it comes into contact with some organic material. The explosion hazard as well as the tendency of ammonium nitrate to cake in a moist atmosphere are removed by reducing the nitrogen content down to 20 per cent, by admixture with powdered lime. Even then the product is still not popular in India. Ammonium chloride may not be suitable for all crops but there is evidence that it is satisfactory for the cultivation of paddy and coconuts.

7. Agronomically, fertiliser nitrogen should be available to soils throughout the period of germination of the seed and its subsequent growth to a plant. For most crops the presence of ammoniacal as well as the nitrate form of nitrogen in a fertiliser is valuable because it provides both the immediate nitrate and deferred ammoniacal supplies of the nitrate. However, with paddy, ammoniacal nitrogen can be taken up directly; this explains the growing popularity of urea in rice cultivation. Products like ammonium nitrate or urea were introduced in the last decade when the high ruling price and occasional scarcity of sulphur gave rise to a desire to avoid its use. This tendency may not persist now because, in the first place, the world trend is towards the production of high analysis complex fertilisers. These require phosphoric acid for their production and the wet process based on sulphuric acid is still the cheapest method for producing phosphoric acid. The prices and availability of sulphur have also improved dramatically in the last few years with the appearance of France, Canada and Poland as suppliers of sulphur in competition to the USA.

Single and Triple Superphosphate.

8. Phosphate rock, of which $\text{Ca}_3(\text{PO}_4)_2\text{CaF}_2$ is the principal constituent, is the source of phosphatic fertilisers. Neglecting the fluorine radical, the molecular ratio of CaO to P_2O_5 varies from 3.4 to 4.2 according to the source of rock. In acid soils or wherever acidity is likely to arise from use of organic manure, finely ground rock phosphate may itself prove satisfactory. The more popular method is to obtain superphosphate by treatment of rock phosphate with acid in which the P_2O_5 is in the water soluble form, i.e., as monocalcium phosphate. Decomposition with sulphuric acid yields single superphosphate, with a P_2O_5 content of 16 to 19 per cent; with phosphoric acid the product obtained is triple superphosphate containing about 45 per cent P_2O_5 . Use of triple superphosphate is often favoured on the ground that

the cost of transport will be substantially lower for handling the more concentrated product. For this reason, some countries in which deposits of phosphate rock as well as sulphur-bearing materials occur together, plan to produce and export triple superphosphate instead of phosphate rock. Since the investment for production of a unit of P_2O_5 is more than twice for triple superphosphate than for single superphosphate, the latter may remain the more acceptable fertiliser unless the savings on freight counterbalance the increased cost of production of triple superphosphate. The relative expenditure of foreign exchange per unit of P_2O_5 in the product will also influence the choice between import of phosphate rock or superphosphate by developing countries.

Nitrophosphates.

9. A large number of complex fertilisers grouped under the generic term Nitrophosphate are made, without using sulphur, by treatment of rock phosphate with nitric acid or a mixture of nitric and other acids, followed by neutralisation of the mixture with ammonia. In order to produce a freely flowing granulated fertiliser with good keeping qualities from this mixture consisting essentially of di-calcium phosphate, ammonium nitrate and calcium nitrate, it is necessary to remove from this mixture two moles of calcium nitrate per every mole of rock phosphate treated. This is done either by precipitation as calcium sulphate, calcium phosphate or calcium carbonate, or by crystallisation and separation of the calcium nitrate by cooling. In all these cases, the precipitated calcium remains in the final product; in the phospho-nitric process it also helps to raise its P_2O_5 content. The processes are flexible enough to permit the making of a final product containing any desired proportion of water soluble P_2O_5 .

10. Nitrophosphate will be one of the products of the Trombay Fertiliser Factory. In order to ensure that the product of the Trombay Factory would be suitable for use in this area where the pH of soils varies from 6.5 to 8.5 and the main crops are paddy and sugarcane, a Government of India technical delegation visited Europe in 1960 to study the problems associated with the use of various forms of Nitrophosphate. The delegation noticed that two divergent views were held by experts in this field. According to one view, if a high C/N ratio is maintained in the soil through the application of organic manures, then mono-calcium and di-calcium phosphates are equally effective and the choice would depend on which was cheaper. Thomas slag is popular in Italy for this reason. It was claimed that plants take up phosphorus from the soil solution, in which the optimum concentration of phosphate ions does not exceed 1.2 mg. per litre. Since the phosphate ion concentration to be obtained with di-calcium phosphate is substantially higher than this value, there is no need to increase it by applying water soluble phosphates. The delegation noted that in conformity with this view, in France a premium in price is allowed per unit of P_2O_5 when it is in the form of di-calcium phosphate.

Several other authorities in Europe, however, hold the opposite view that for short-term crops in particular an adequate proportion of water soluble P_2O_5 is essential for ensuring rapid early growth of crops. This requirement was stated to be of special importance in areas where phosphate reserves in the soil have still to be built up. The Indian delegation agreed with this view and recommended as a safe approach to the problem that Nitrophosphate applied to paddy should contain between 30 and 40 per cent of water soluble phosphate.

Raw Materials for Ammonia Synthesis.

11. Ammonia is the first step in the production of nitrogenous fertilisers. Ammonia is made by catalytic synthesis under pressure from a gas mixture consisting of hydrogen and nitrogen in the ratio of 3:1. Liquefaction of air followed by distillation gives Nitrogen. For Hydrogen, there are many processes and the choice depends on the availability of raw materials and the cost of production. Electrolytic hydrogen or processes based on coal gas, natural gas, petroleum refinery gases, coal, coke or petroleum naphtha are the usual sources.

Partial oxidation of the fuels with air or oxygen yields carbon monoxide and hydrogen. The carbon monoxide is then oxidised with steam to carbon dioxide, and the latter is removed by scrubbing with water under pressure. The use of oxygen is preferred because it is available as a by-product in the separation of nitrogen or in the production of electrolytic hydrogen. In fact, in order to utilise the oxygen fully, it is now customary to adjust the proportion of electrolytic hydrogen and hydrogen derived by partial oxidation of liquid or gaseous hydro-carbons.

12. As stated earlier, the choice of a raw material or process for hydrogen will be governed largely by the cost of its production. Coke was used quite commonly in the forties. Its use has, however, receded in recent years partly because it is becoming increasingly difficult to obtain adequate supplies of coal that yields coke oven gas as well as coke of satisfactory quality for gassification in the desired ratio. Also, the investment on plant and equipment is about 30 per cent higher than that for hydrogen from liquid or gaseous feedstocks. Electrolytic hydrogen is no longer popular partly because it is expensive and also because in most countries it is now considered unwise to use electricity for this purpose when several urgent demands for power compete with each other. Natural gas or petroleum refinery gases are preferred if they are available at a reasonable price. During the last few years, light petroleum naphtha has also become the preferred raw material in many parts of the world, wherever surplus of naphtha is available at a favourable price.

It is sometimes argued that whenever surplus naphtha is available in a country as it is likely to be in India for the next few years, all such naphtha should be earmarked for production of nitrogenous fertilisers. The reason put forward in support of such a plea is that ammonia production based on naphtha will ensure a low price for fertilisers even if they have to be transported over long distances. While making this claim, it is assumed however that on a thermal equivalent basis the price of naphtha would be equivalent to that of other carbonaceous raw materials available in the country, and freight rates on naphtha will be low so as to permit its use in the production of synthesis gas at considerable distances from the Refineries. Unfortunately these conditions are not existent in India.

The price of coal per tonne at the pit-head is about one-fourth of the price of naphtha, without excise duty, at the Refineries. The freight rates on coal are the lowest, whereas naphtha must be transported at the higher rates applicable to dangerous petroleum. Also, naphtha can be used readily to produce organic chemicals as well as fertilisers, but not coal or coke. It would therefore appear that naphtha is not necessarily the only raw material that will produce fertilisers at a low price, and that under circumstances described above, coal will be equally satisfactory at some locations.

Changing Trends in Fertiliser Production in India:

13. The changing trends in production and raw materials have been reflected in the development of the nitrogenous fertiliser industry in India. The first unit was established at Belagula in Mysore in 1939, based on electrolytic hydrogen, with a capacity for production of only 25 tonnes per day of ammonium sulphate. Planning for the second unit at Alwaye in Kerala began in 1943. It was felt at that time that forest wood would be the cheapest carbonaceous material in Kerala. Therefore, the unit was designed to operate on hydrogen from gassification of wood. When it started in 1947, the factory had a capacity for ammonium sulphate equivalent to 10,000 tonnes N per year, employing gypsum. A rapid increase in labour costs for collection and transport of wood led to the use of electrolytic hydrogen for the first expansion in capacity of 10,000 tonnes N per year. Also, a further expansion in capacity was contemplated on the basis of electrolytic hydrogen. In the meanwhile, it appeared that naphtha would soon become available in the country at a reasonable price. The plans were therefore changed so as to eliminate altogether the use of hydrogen obtained by gassification of wood, and raise the capacity to 60,000 tonnes N per year, with electrolytic and naphtha based hydrogen in the proportion of 1 to 5. The first phase of expansion will be completed this year with an increase in the capacity up to 30,000 tonnes N and closure of the wood gassification plant. A capacity of 60,000 tonnes N

will be achieved in 1964 when the expansion programme is fully implemented, the products being ammonium sulphate, ammonium phosphate and ammonium chloride.

The first really large fertiliser factory, set up at Sindri, started production in 1951. Its initial capacity was for 70,000 tonnes of N as ammonium sulphate, based on hydrogen from coke, and gypsum. Initially coke was obtained from merchant coke ovens. Two years later, the factory set up its own coke ovens so that coke as well as coke oven gas became available for the production of hydrogen. When the plan was made in 1955 for expansion of the production capacity at Sindri to 115,000 tonnes N, inclusive of some urea and ammonium sulphate-nitrate among the products, there was a corresponding increase in the coke oven capacity. The desired ratio between coke and coke oven gas could not be maintained, however, because of non-availability of the desired quality of coal in adequate amounts, and consequently production at Sindri has been affected. Various suggestions have been made for restoring the balance. These include the production of hydrogen either directly from coal in slagging generators or from naphtha.

A decision to set up a large fertiliser factory at Nangal in the Punjab was taken in 1954. At that time, the possibility that naphtha could be used as a source of hydrogen for ammonia synthesis had not become apparent in India; nor did the prospect of transporting coal from Bihar, a distance of several hundred miles, appear attractive. The construction of a 400 megawatt hydro-electric power project at nearby Bhakra had already commenced at that time. It was, therefore, decided that the Nangal Factory should undertake integrated production of heavy water as well as fertilisers from electrolytic hydrogen. The capacity for fertilisers was for 80,000 tonnes N in the form of calcium ammonium nitrate (20 per cent N). The Factory started production in 1961.

Although production of fertilisers from petroleum refinery gases at Trombay in Bombay has been under consideration since 1955, the decision to set up a factory was taken only in 1959. This unit will have a capacity of 90,000 tonnes N, as urea and nitro-phosphate, and hydrogen will be obtained from refinery gases and naphtha in approximately equal proportions. It is expected that when this factory comes on stream in 1964, its cost of production of ammonia will be the lowest in the country.

Fertiliser Production Programme in India.

14. In 1961 India produced 134,500 tonnes N mainly in the form of ammonium sulphate, calcium ammonium nitrate, ammonium sulphate-nitrate (double salt), and urea. The target

for production of nitrogenous fertilisers for the last year of the Third Five Year Plan, i.e., 1965-66, was set initially at one million tonnes of N. The programmes of expansion of existing units as well as of new units for which firm commitments have been made, show that a capacity of at least 0.84 million tonnes N will be available by 1965-66. The details of all these units, including the types of products proposed and the raw materials that will be used are summarised in Table II (pages 9 & 10). The data show that ammonium sulphate, urea and ammonium phosphate are the most favoured fertilisers, and that coal and coke will continue to be used as raw materials for their production.

TABLE II
PROGRAMME OF FERTILISER PRODUCTION IN INDIA
BY 1965-66.

Name of Unit	Raw Material	End Products	Production capacity in Tonnes N/year.
<u>I. Existing Units (inclusive of Expansion)</u>			
1. Mysore Chemicals And Fertilisers Ltd., Belagula, Mysore.	Electrolytic Hydrogen	Ammon-Sulph. ...	1,320
2. Fertilisers & Chemicals (Travancore) Ltd., Alwaye (Kerala)	Electrolytic Hydrogen and Naphtha.	Ammon-Sulph. ... Ammon-Phos. ... Ammon-Chloride...	33,000 21,000 6,000
3. Fertiliser Corporation of India, unit at Sindri (Bihar)	Coke and Coke Oven Gases.	Ammon-Sulph. ... Ammon-Sulph.-Nitrate ... Urea ...	70,000 36,000 11,000
4. Fertiliser Corporation of India, unit at Nangal (Punjab)	Electrolytic Hydrogen	Cal-Ammon-Nitrate ...	80,000
5. Sahu Chemicals Ltd. Varanasi (Uttar Pradesh)	Coke	Ammon-Chloride...	10,000
Total ...			<u>268,320</u>

Name of Unit	Raw Material	End Products	Production capacity in Tonnes N/year
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II. Units under Construction and Design.

1. Unit of Hindustan Steel Ltd. at Rourkela (Orissa)	Coke Oven Gases	Cal-Ammon-Nitrate...	120,000
2. East India Distilleries And Sugar Factories Ltd., Ennore (Madras)	Naphtha	Ammon-Phos.	... 16,500
3. Neyveli Lignite Corp., Neyveli (Madras)	Lignite	Urea	... 70,000
4. Unit of the Fertiliser Corp. of India at Trombay (Bombay)	Refinery Gases and Naphtha	Urea	... 45,000
		Nitro-Phos.	... 45,000
5. Unit of the Fertiliser Corp. of India at Namrup, Nahorkatiya (Assam)	Natural Gas	Ammon-Sulph.	... 20,000
		Urea	... 25,000
6. Unit of the Fertiliser Corp. of India at Gorakhpur (Uttar Pradesh)	Naphtha	Urea	... 80,000
7. Andhra Sugars Ltd. at Kothagudem (Andhra Pradesh)	Coal	Urea	... 66,000
8. Parry & Co. Ltd. at Vishakhapatnam (Andhra Pradesh)	Naphtha	Urea	... 8,000
		Ammon-Phos.	... 72,000
Total			... 567,500

TOTALS OF I & II	...	268,320 Tonnes (I)
		N/year
		567,500 " (II)
		835,820 Tonnes
		N/year.